Summary

- Hazard – Dam Hazard is a term indicating the potential hazard to the downstream area resulting from failure or mis-operation of the dam or facilities. The potential impact of a dam, dike or levee failure in Washington State could result in a flood event. The amount of water impounded is measured in acre-feet, in which an acre-foot of water is the volume that covers an acre of land to a depth of one foot. Dam failures are not routine; two factors influence the potential severity of full or partial dam failure: (1) The amount of water impounded, and (2) the density, type, and value of development downstream.

- Previous Occurrences – Since 1918, the Washington State Department of Ecology reports15 dam-failure events, resulting in nine lost lives. A complete list of dam failures is attached as Appendix A at the end of this profile.

- Probability of Future Events – Dam failure or levee breeches can occur with little warning. Intense storms may produce a flood in a few hours or even minutes for upstream locations. Flash floods occur within six hours of the beginning of heavy rainfall, and dam failure may occur within hours of the first signs of breaching. Other failures and breeches can take much longer to occur, from days to weeks, as a result of debris jams or the accumulation of melting snow. You should note that the overall probability of a dam failure is generally quite low for most dams, typically less than a 500-year flood.

- Jurisdictions at Greatest Risk – This summary will not address any one specific dam within a particular jurisdiction or region in an attempt to determine risk, and will only supply information.

- Special Note – The intent behind this hazard profile is not to provide an all-encompassing source of information, but to increase awareness of the potential impact from this hazard. Therefore, this profile will not attempt to estimate potential losses. This profile will only provide information on the dams within the State. The Washington State Department of Ecology remains the primary source of information and subject matter experts for Dam related issues.

Introduction: [1]

Under Washington state law, the Department of Ecology (Ecology) is responsible for regulating dams that capture and store at least 10 acre-feet (about 3.2 million gallons) of water or watery materials such as mine tailings, sewage and manure waste.

The first dam safety law in Washington was passed as part of the state water code in 1917 (RCW 90.03.350) This law required that engineering plans for any dam that could impound 10 or more acre-feet had to be reviewed and approved by the state before construction could begin. Over the years, the Department of Conservation and

Development, then the Department of Water Resources performed this function. In 1970, responsibility transferred to the new Department of Ecology.

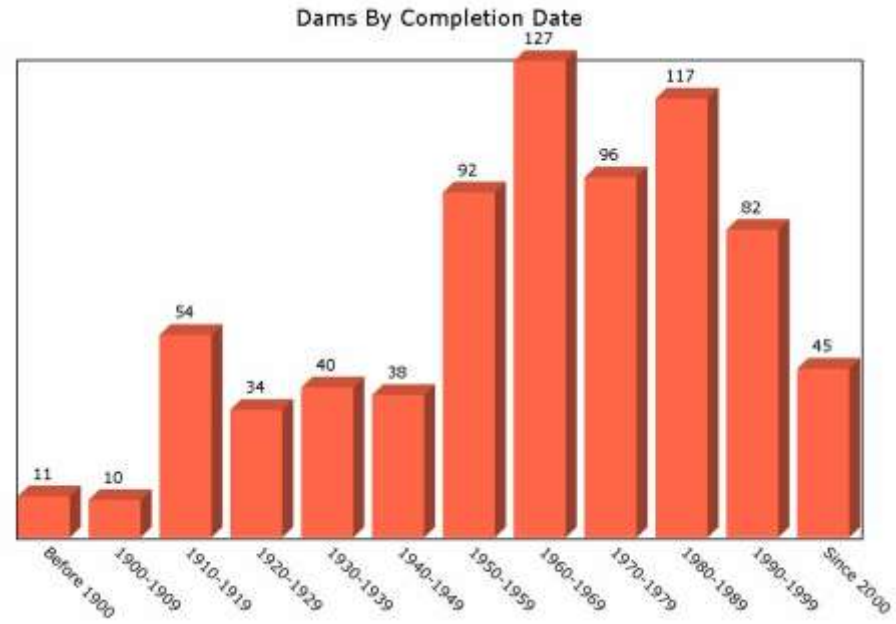
In 1972, the U.S. Congress passed Public Law 92-367 which authorized the development of a National Inventory of Dams (NID). Subsequently in 1975, the Washington State Department of Ecology assembled the first dam inventory list for our state, which includes all dams owned within our boundaries. The list compiled by the Department of Ecology maintains 1,125 dams, while the current numbers represented on the National Inventory of Dams lists 746 dams.

In order for a dam to be placed on the NID list, the dam must meet at least one of the following criteria:

1. High hazard classification - loss of one human life is likely if the dam fails
2. Significant hazard classification - possible loss of human life and likely significant property or environmental destruction
3. Equal or exceed 25 feet in height and exceed 15 acre-feet in storage
4. Equal or exceed 50 acre-feet storage and exceed 6 feet in height

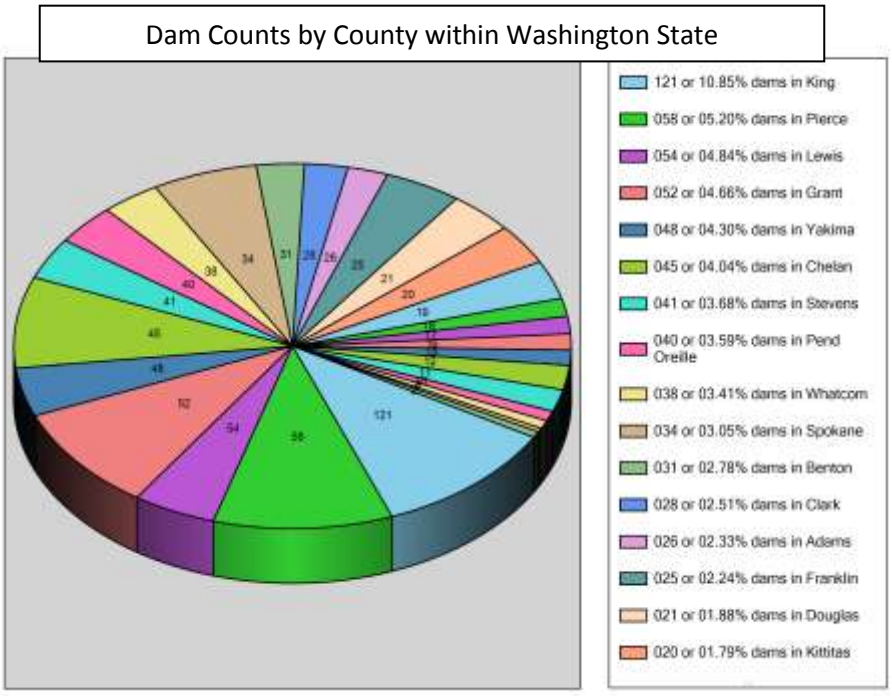
In Washington, besides regulating dams that meet the NID requirements, there are over 370 dams which do not meet one of the four criteria above, but do fall under the 10 acre-foot jurisdictional level. Ecology's Dam Safety Office currently oversees 996 of the 1,125 dams across the state. Through plan reviews and construction inspections, the agency helps ensure these facilities are properly designed and constructed. To reasonably secure the safety of human life and property, Ecology also conducts inspections of existing dams to assure proper operation and maintenance.

The ages of dams in Washington vary from 11 dams constructed pre-1900, to more than 50 dams being completed since 2000. The age of a dam is also a factor in the stability, as many dams are constructed for a specified number of years, as well as the integrity of the materials used to construct the dam may deteriorate over time.



Source: U.S. Corps of Engineers, National Dam Inventory. Available at https://rsgis.crrel.usace.army.mil/apex/f?p=397:3:4299685936885593::NO::P3_STATES:WA

The graphic below illustrates a breakdown of dams by county within Washington State:



Source: Washington State Department of Ecology. Available at: http://www.ecy.wa.gov/pubs/94016.pdf

Dam Distribution by Classification and Purpose Codes:[2,3]

All dams are assigned a high, significant, or low hazard classification based on potential of loss of life and damage to property should the dam fail. This classification is considered the *Dam Hazard*, and indicates the potential hazard to the downstream area resulting from failure or mis-operation of the dam or facilities. Classifications are updated based on development and changing demographics upstream and downstream. The description for each of the different hazard classifications is as follows:

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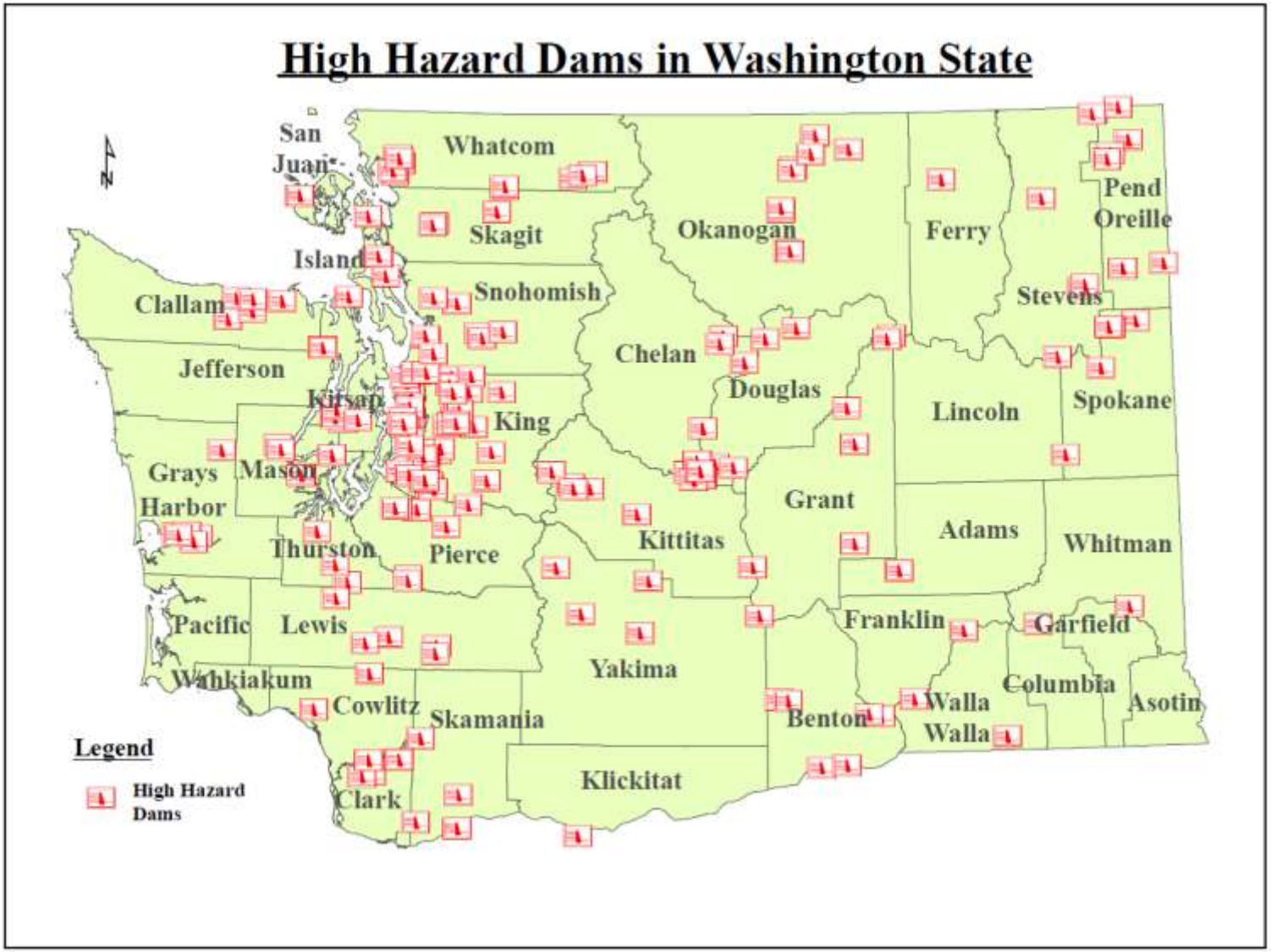
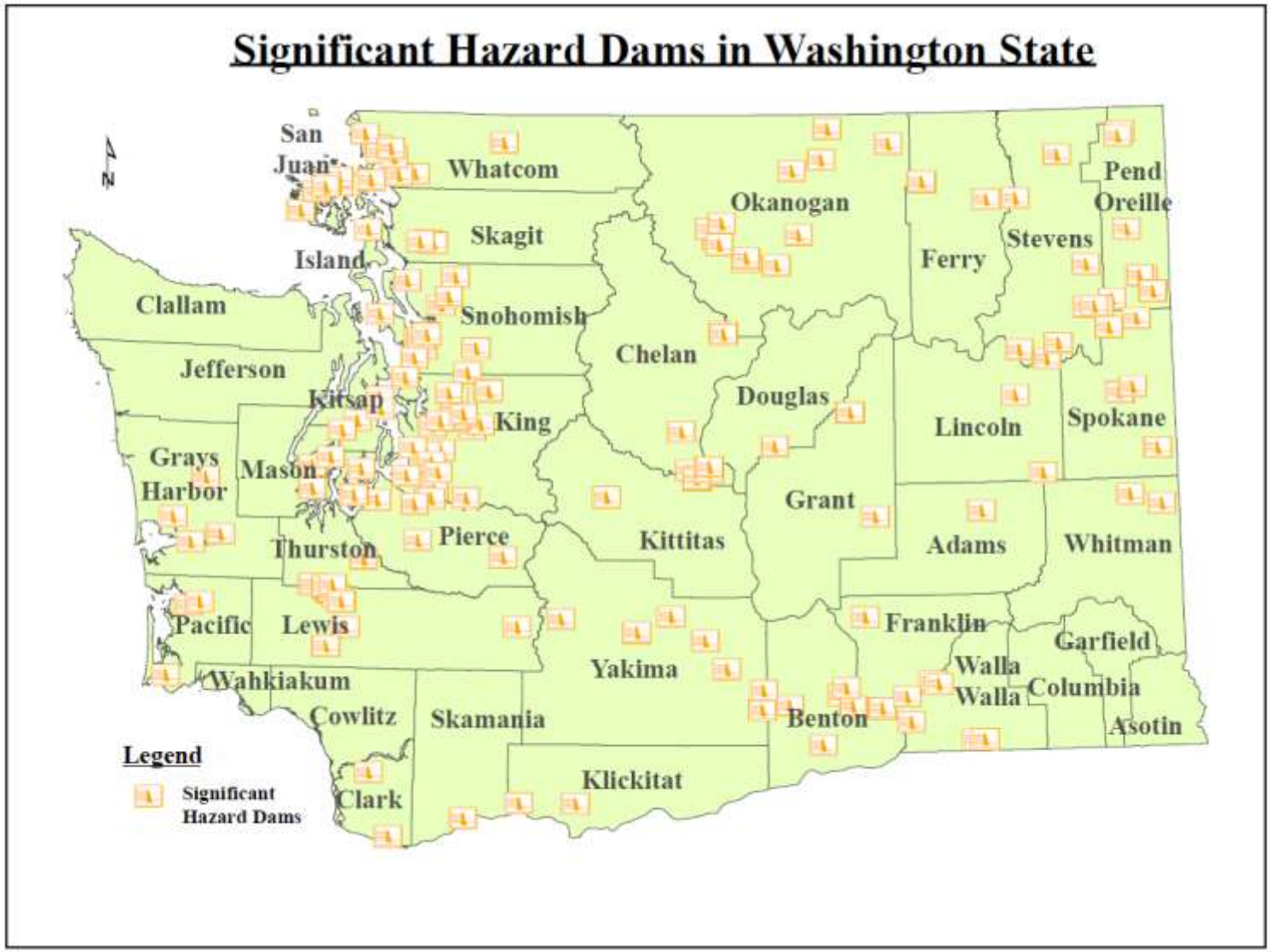
- Low - A dam where failure or mis-operation results in no probable loss of human life and low economic and/or environmental loss. Losses are principally limited to the owner's property.

- Significant - A dam where failure or mis-operation results in no probable loss of human life but can cause economic loss, environmental damage, disruption of lifeline facilities, or impact other concerns. These dams are often located in predominantly rural or agricultural areas but could be located in areas with more dense populations and significant infrastructure.

- High - A dam where failure or mis-operation will probably cause loss of human life.

The following maps demonstrate the general location of the dams within Washington's borders.


High Hazard Dams in Washington State
San Juan
Whatcom
Skagit
Island
Snohomish
Okanogan
Ferry
Pend Oreille
Stevens
Clallam
Jefferson
Kitsap
King
Chelan
Douglas
Lincoln
Spokane
Grays Harbor
Mason
Thurston
Pierce
Kittitas
Grant
Adams
Whitman
Pacific
Lewis
Yakima
Franklin
Garfield
Wahkiakum
Cowlitz
Skamania
Benton
Walla Walla
Columbia
Asotin
Klickitat
Clark
Legend
High Hazard Dams


Significant Hazard Dams in Washington State
N
San Juan
Whatcom
Skagit
Island
Snohomish
Clallam
Jefferson
Kitsap
King
Grays Harbor
Mason
Pierce
Thurston
Pacific
Lewis
Wahkiakum
Cowlitz
Skamania
Clark
Klickitat
Yakima
Kittitas
Chelan
Okanogan
Douglas
Grant
Ferry
Stevens
Pend Oreille
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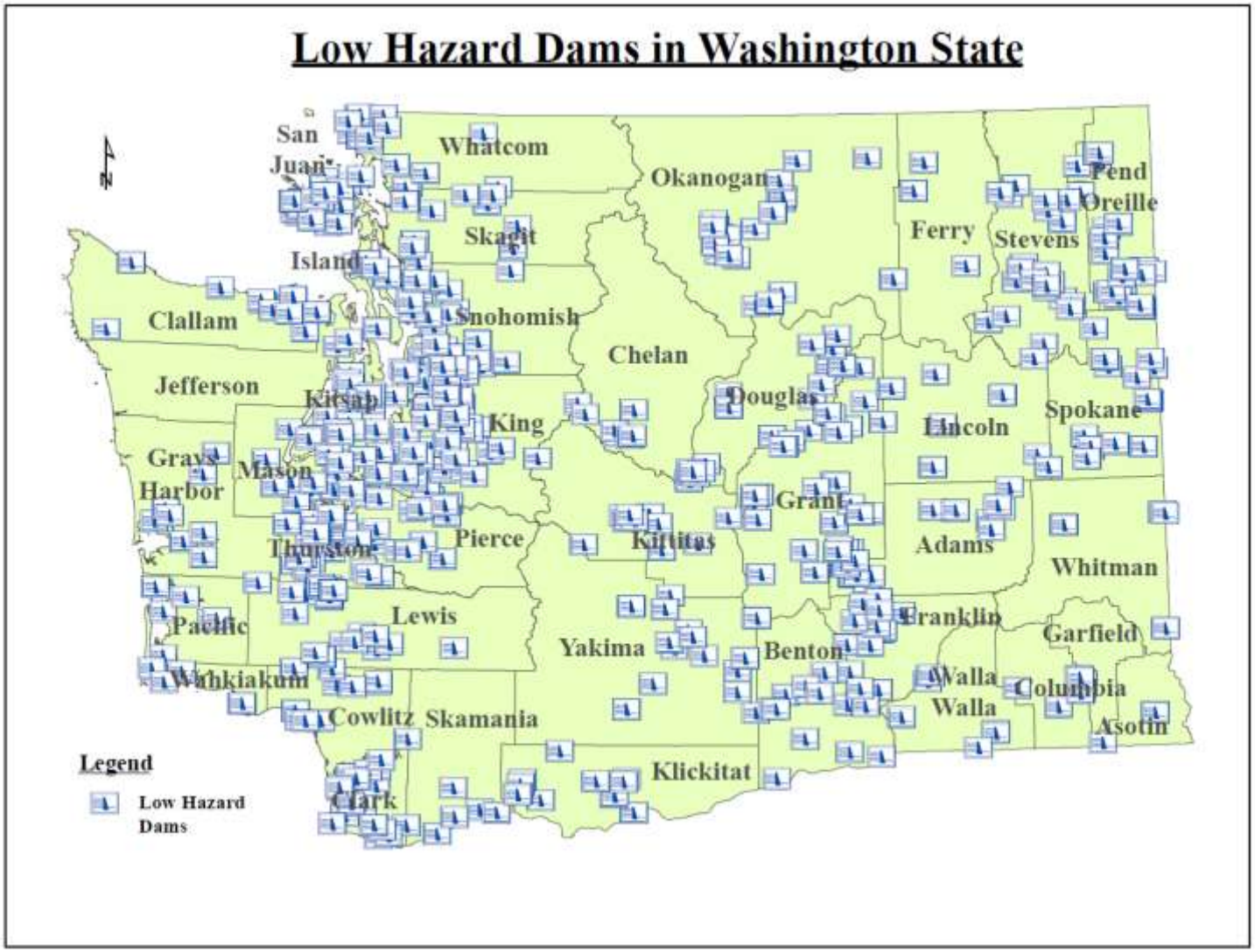
Spokane
Adams
Whitman
Franklin
Garfield
Walla Walla
Columbia
Benton
Asotin
Legend
Significant Hazard Dams


Low Hazard Dams in Washington State
San Juan
Whatcom
Okanogan
Pend Oreille
Skagit
Ferry
Stevens
Island
Snohomish
Clallam
Chelan
Jefferson
Kitsap
Douglas
Spokane
King
Lincoln
Grays Harbor
Mason
Grant
Pierce
Kittitas
Adams
Thurston
Whitman
Lewis
Franklin
Pacific
Garfield
Yakima
Benton
Walla Walla
Wahkiakum
Columbia
Cowlitz
Skamania
Asotin
Klickitat
Legend
Low Hazard Dams
Clark

In addition to the Dam Classification, purpose codes are assigned to each dam as illustrated in the tables below.

Table 1. Dam Hazard Classification

DOWNSTREAM HAZARD POTENTIAL	DOWNSTREAM HAZARD CLASS	POPULATION AT RISK	ECONOMIC LOSS GENERIC DESCRIPTION	ENVIRONMENTAL DAMAGE
LOW	3	0	Minimal. No inhabited structures. Limited agricultural development.	No deleterious material in reservoir contents.
SIGNIFICANT	2	1 - 6	Appreciable. 1 or 2 inhabited structures. Notable agriculture or work sites. Secondary highway and/or rail lines.	Limited water quality degradation from reservoir contents and only short term consequences.
HIGH	1C	7 - 30	Major. 3 to 10 inhabited structures. Low density suburban area with some industry and work sites. Primary highways and rail lines.	Severe water quality degradation potential from reservoir contents and long term effects on aquatic and human life.
HIGH	1B	31 - 300	Extreme. 11 to 100 inhabited structures. Medium density suburban or urban area with associated industry, property, and transportation features.	Severe water quality degradation potential from reservoir contents and long term effects on aquatic and human life.
HIGH	1A	More than 300	Extreme. More than 100 inhabited structures. Highly developed, densely populated suburban or urban area with associated industry, property, transportation, and community life line features.	Severe water quality degradation potential from reservoir contents and long term effects on aquatic and human life.

TABLE 2. Dam Height Classification

DAM CLASS SIZE	DAM HEIGHT	DAM COUNT	DAM PERCENT
SMALL	6 - 14 Feet	508	45.56 %
INTERMEDIATE	15 - 49 Feet	494	44.30 %
LARGE	50 Feet or more	113	10.13 %

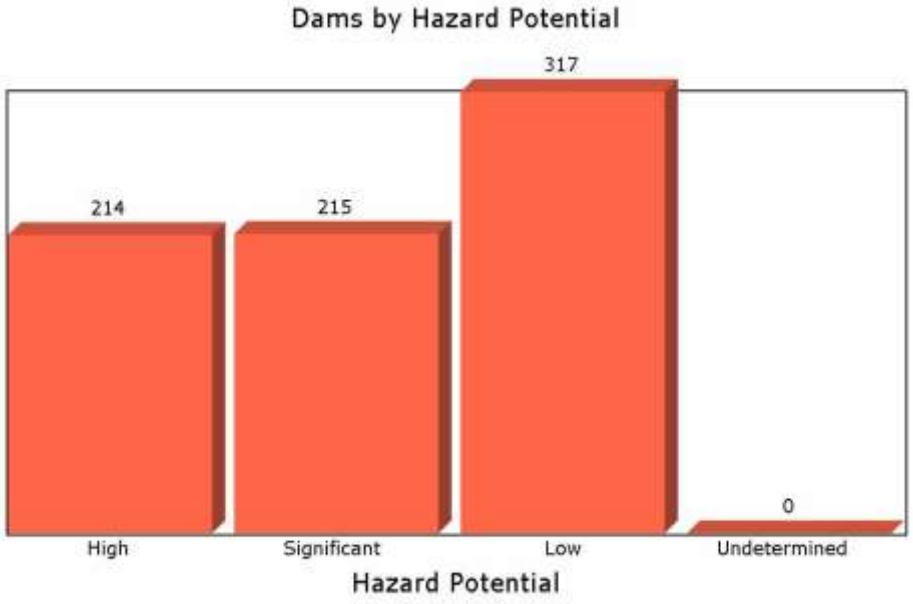
Table 3. Dam Purpose Codes

CODE DESCRIPTION	CODE
Flood Control and Storm Water Management	C
Debris Control	D
Fish and Wildlife	F
Grade Stabilization	G
Hydroelectric	H
Irrigation	I
Navigation	N
Other	O
Fire Protection, Stock, or Small Farm Pond	P
Water Quality	Q
Recreation	R
Water Supply	S
Tailings	T

Table 4. Dam Type Codes

CODE DESCRIPTION	CODE
Concrete Buttress	CB
Concrete	CN
Rock Fill	ER
Masonry	MA
Concrete Multiple Arch	MV
Other Type	OT
Concrete Gravity	PG
Earth Fill	RE
some access	SA
Stone	ST
Timber	TI
Concrete Single Arch	VA

A breakdown of dam classification for Washington State dams is as follows:



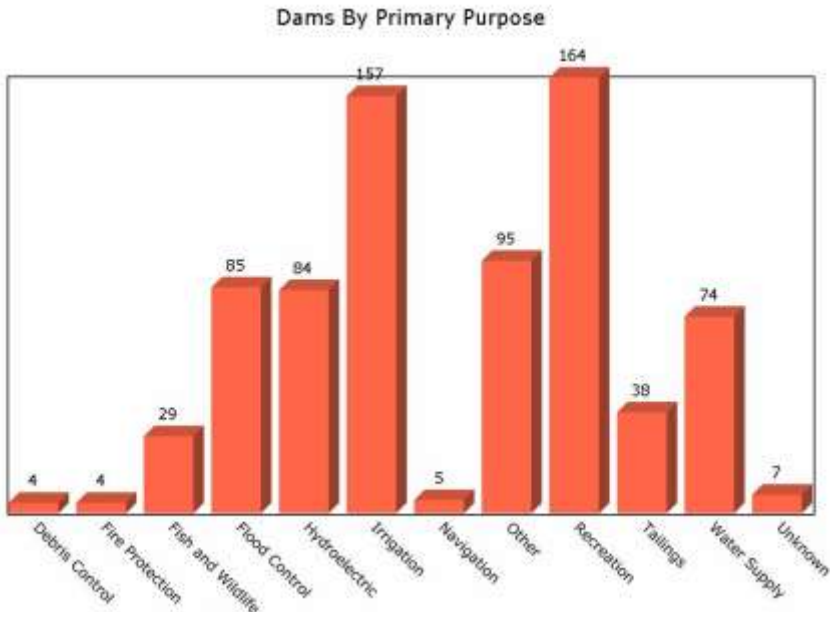
Source: U.S. Corps of Engineers, National Dam Inventory. Available at https://rsgis.crrel.usace.army.mil/apex/f?p=397:3:4299685936885593::NO::P3_STATES:WA

Purpose:
Dams and reservoirs in Washington are constructed for a variety of purposes, including:

- ✓ Irrigation
- ✓ Domestic water supply
- ✓ Recreation
- ✓ Water quality
- ✓ Hydropower
- ✓ Flood control
- ✓ Mine tailings storage.

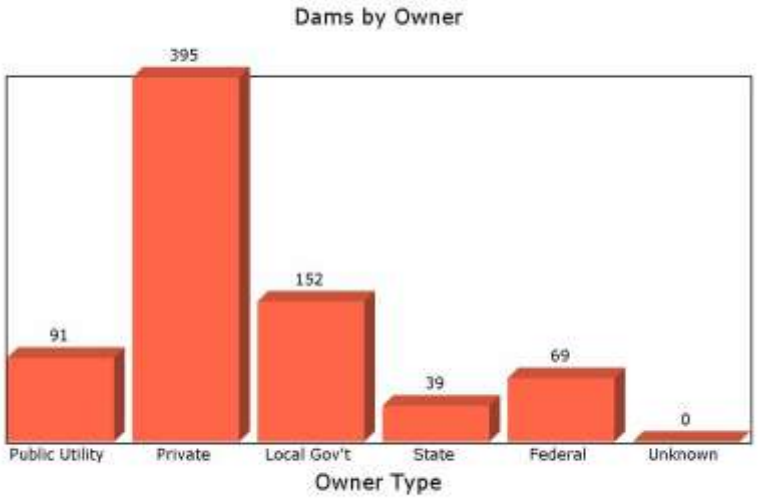
In addition to the above, the larger reservoirs are commonly multi-purpose and serve a number of functions. In addition to man-made dams, here are also dams created by nature – such as beaver dams, as well as debris dams which occur after rapidly running water collects debris as it travels, or after flooding events.

The breakdown of dams by primary purpose is as follows:



Source: U.S. Corps of Engineers, National Dam Inventory. Available at https://rsgis.crrel.usace.army.mil/apex/f?p=397:3:4299685936885593::NO::P3_STATES:WA

Ownership:
As there are a wide variety of dam and reservoir purposes, there is a correspondingly wide category of dam owners. To help delineate the types of owners, they have been separated into five categories: private, local government, public utilities, federal, and state. The breakdown is as follows:



Source: U.S. Corps of Engineers, National Dam Inventory. Available at https://rsgis.crrel.usace.army.mil/apex/f?p=397:3:4299685936885593::NO::P3_STATES:WA

Dam Failure:
A number of outside forces can cause dam failure, including prolonged periods of rain or flooding, landslides into reservoirs, failure of dams upstream, high winds, and earthquakes.

Failure due to natural events such as earthquakes or landslides is significant because there is little to no advance warning. It is important to note that dam failures can result from natural events, human-induced events, or a combination of the two. Improper design and maintenance, inadequate spillway capacity, or internal erosion or piping within a dam may also cause failure. People, property, and infrastructure downstream of dams are subject to devastating damage in the event of failure.

According to Washington State Department of Ecology, there are several reasons for dam failures, including:[4]

- Overtopping - 34% of all failures (nationally)
  - Inadequate Spillway Design
  - Debris Blockage of Spillway
  - Settlement of Dam Crest

- Foundation Defects - 30% of all failures (nationally)
  - Differential Settlement
  - Sliding and Slope Instability
  - High Uplift Pressures

- Uncontrolled Foundation Seepage

- Piping and Seepage - 20% of all failures (nationally)
  - Internal Erosion Through Dam Caused by Seepage-"Piping"
  - Seepage and Erosion Along Hydraulic Structures Such as Outlet
  - Conduits or Spillways, or Leakage Through Animal Burrows
  - Cracks in Dam

- Conduits and Valves - 10% of all failures (nationally)
  - Piping of Embankment Material Into Conduit Through Joints or Cracks

- Other - 6% of all failures (nationally)

Since 1918, 18 dam failures have occurred within Washington State, the latest occurring in 2010. An itemized list of dam failures attached at the end of this section. The two most severe of these dam failures took the lives of 9 people total. The first incident occurred in 1932 near North Bend, when a slide caused water to back up, and the Eastwick Railroad fill Dam to fail, killing 7 people.

The second most significant occurred in July 1976 near Auburn when a surge in flow caused by increased discharge from Mud Mountain Dam and removal of flashboards at Diversion Dam killed two children playing in the White River.

The most recent failure occurred in April 2010, when the 12 million gallon French Slough Dairy Waste Pond Failed in Snohomish County.

Currently, Washington State is also experiencing one potentially serious dam safety issue on the Howard Hanson Dam.

Howard Hanson Dam[5, 6]

The Howard Hanson Dam is an earthen dam located near the headwaters of the Green River in King County. The dam was constructed by the U.S. Army Corps of Engineers and went into operation in 1961 for the purpose of flood control for the Green River Valley (1). The dam and the levees along the Green River have provided effective flood control over the years. However, during the storms in January 2009, structural weaknesses were discovered, specifically, two depressions on the right abutment to the flood control dam was weakened by heavy rains. Officials warned the dam would not be able to hold a full reservoir and there was a risk of flooding through the Green River Valley.

Initially the Army Corps of Engineers notified the City of Auburn of the situation and advised of the potential to release more water than usual during extreme rain events. As

a result, it was determined that parts of Auburn were at a higher risk of flooding. It was felt the situation would continue for approximately 18-24 months, or potentially longer depending on the nature of the repair work which needed to be completed at the dam.

Since discovering the problem, the Army Corps of Engineers has completed interim repairs at the Howard Hanson Dam which has reduced the risk of flooding along the Green River Valley from 1 in 3 to 1 in 25. However, the risk is still significant and individuals and businesses have been encouraged to continue their efforts to prepare for and mitigate against the risk of flooding. Great emphasis was put on public education with respect to evacuation, sheltering and flood insurance.

As of January 2010, millions of dollars were spent to add sandbags on levees through Kent, Renton, Auburn and Tukwila. In addition to the repair work completed the Corps, these temporary repairs have also helped reduced the risk of flooding. While the dam itself is not in immediate danger of failing, as of April 2010, there remains an increased risk to downstream communities until seepage issues with the right abutment have been addressed.

APPENDIX 1

Notable Dam Failures and Incidents In Washington State

Project Name	Location	Date of Failure	No. of Lives Lost	Nature of Failure and Damage
Masonry Dam (Boxley Burst)	Near North Bend	December 1918	0	Excessive seepage through glacial moraine abutment caused mud flow about 1 mi. from reservoir. Destroyed RR line and village of Eastwick.
Eastwick RR Fill Failure	Near North Bend	February 1932	7	Blockage of culvert by slide caused RR Fill to back up water and fail. Destroyed RR line and village of Eastwick.
Loup Loup Dam	Near Malott	April 1938	0	50 foot high hydraulic fill dam failed when emergency spillway was undercut during a flood. Destroyed 25 homes and left 75 people homeless. Destroyed 1/2 mile of state highway.
Lake Dawn Dam	Port Angeles	February, 1950	0	Heavy Rains caused overtopping and failure of earthen dam. 1 home destroyed, $4000 damage
North Star Sand & Gravel Dams	Everett	December 1967	0	40 foot high dam washed out by overtopping due to lack of spillway. 25 foot high dam rebuilt, also failed, washed out GN railroad tracks, derailed passing train.
Pillar Rock Dam	Wahkiakum County	January 1970	0	Logging roadfill culvert blocked by debris, overtopped and failed, caused 25 foot high concrete gravity dam to fail. 3 homes and fish cannery destroyed.
Sid White Dam	Near Omak	May 1971	0	Earthen dam failed due to seepage through animal burrows. Caused second dam to fail and dumped debris into town of Riverside.
Horseshoe Lake Blowout	Chewelah	May 1974	0	Outlet tunnel through 50 foot high natural ridge collapsed causing ridge to fail. Drained 20 foot deep lake. Extensive flood damage and debris deposits on cropland in downstream valley.

Notable Dam Failures and Incidents In Washington State

Project Name	Location	Date of Failure	No. of Lives Lost	Nature of Failure and Damage
White River Incident	Near Auburn	July 1976	2	Surge in flow caused by increased discharge from Mud Mountain Dam and removal of flashboards at PP&L Diversion Dam. Killed 2 children playing in White River
Alexander Lake Dam	Near Bremerton	December 1982	0	Spillway undermined and failed during heavy rains. Caused damage at fish hatchery and homes in Gorst.
Upriver Dam	Spokane	May 1986	0	Hydropower facility failed by overtopping. Lightning struck system, turbines shut down. Water rose behind dam while trying to restart. Backup power systems failed, could not raise spillway gates in time. Caused $11 million damage to facility.
Chinook Dam	Pacific County	November 1990	0	Heavy rains overtopped the embankment and undermined the spillway, leading to failure of dam. Approximately $100,000 damage to facility.
Seminary Hill Reservoir City of Centralia	Centralia	October 1991	0	Failure along weak rock zone in hillside caused massive slide which breached reservoir. 3 million gallons of water drained from reservoir in 3 minutes. 2 homes destroyed, many homes damaged, $3 million in damage.
Iowa Beef Processors Waste Pond Dam No. 1	Wallula near Richland	January 1993	0	Failure of 15-foot high embankment released 300 acre-feet of waste water. Failure attributed to high reservoir levels due to snowmelt, entering animal burrows near embankment crest, and eroding dam. Washed out Union Pacific RR tracks, derailed 5 locomotives. $5 million in damage.

Source: Washington State Dept. of Ecology. Available at: http://www.ecy.wa.gov/programs/wr/dams/Reports/damfailure_ws.pdf

[1] Washington State Department of Ecology. (2009). Inventory of Dams in Washington State. Accessed: March 29, 2010. Available at: http://www.ecy.wa.gov/pubs/94016.pdf

[2] Washington State Department of Ecology. (2006). 2006 Report to the Legislature: Status of High and Significant Hazard Dams in Washington with Safety Deficiencies. Accessed: 29 March 2010. Available at: http://www.ecy.wa.gov/programs/wr/dams/Reports/Legislature/06110472006.pdf

[3] Washington State Department of Ecology. (2009). Inventory of Dams in Washington State. Accessed: March 29, 2010. Available at: http://www.ecy.wa.gov/pubs/94016.pdf

[4] Washington State Department of Ecology. (2009) Reasons for Damn Failure. Accessed 29 March 2010. Available at: http://www.ecy.wa.gov/programs/wr/dams/failure.html

[5]Associated Press. Seattle Times. *Lawmakers ask Corps for prompt Green River dam fix*. 4 Feb. 2010. Accessed 29 March 2010. Available at: http://seattletimes.nwsource.com/html/localnews/2010981891_apwagreenriverflooding.html

[6] Washington State Emergency Management. Green River Valley. Accessed: 30 March 2010. Available at: http://www.emd.wa.gov/activations/GreenRiverFlooding.shtml